US012162330B2

(12) **United States Patent**
Wilson et al.

(10) **Patent No.: US 12,162,330 B2**
(45) **Date of Patent: Dec. 10, 2024**

(54) **MULTI-LAYER WINDSHIELD FILM HAVING PROGRESSIVE THICKNESS LAYERS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/937,371**

(22) Filed: **Sep. 30, 2022**

(65) **Prior Publication Data**

US 2023/0249524 A1 Aug. 10, 2023

Related U.S. Application Data

(60) Provisional application No. 63/267,686, filed on Feb. 8, 2022.

(51) **Int. Cl.**
B60J 1/20 (2006.01)
B32B 7/12 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B60J 1/2094*** (2013.01); ***B32B 7/12*** (2013.01); ***B32B 27/08*** (2013.01); ***B32B 27/36*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC Y10T 428/24942; Y10T 428/2495; Y10T 428/24959; Y10T 428/24967;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,337,036 A 4/1920 Bergmann
1,366,907 A 2/1921 Dunand
(Continued)

FOREIGN PATENT DOCUMENTS

AU 2005244595 A1 7/2006
AU 2015277196 A1 1/2017
(Continued)

OTHER PUBLICATIONS

www.wikipedia.org. "Black Body", Jul. 2009, 11 pages.
(Continued)

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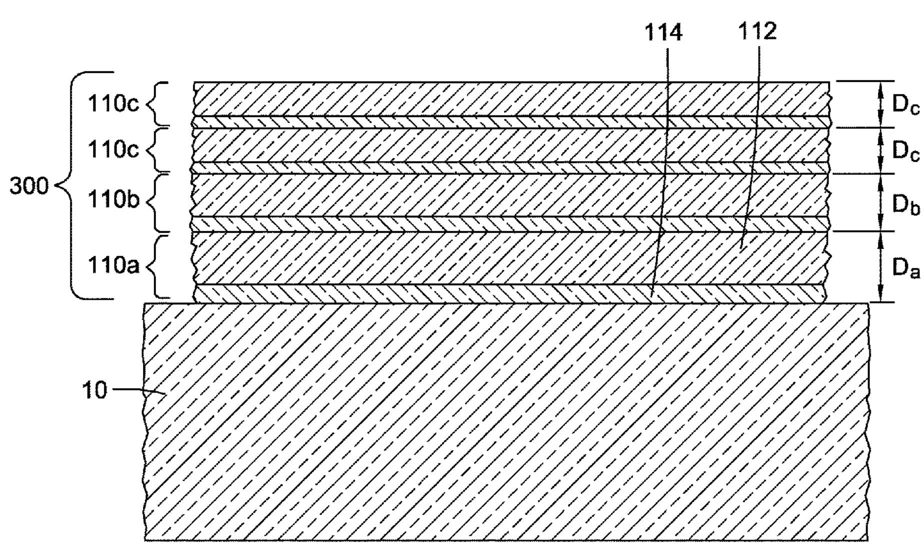
(57) **ABSTRACT**

A protective barrier is affixable to a curved substrate such as a vehicle windshield. The protective barrier may include a stack of three or more lenses. Each of the three or more lenses may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film) and an adhesive layer on a first side of the thermoplastic film. The three or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses. The protective barrier may be placed on the curved substrate with the adhesive layer of an innermost lens of the stack in contact with the curved substrate, and heat and pressure may be applied to conform the stack to the shape of the curved substrate. Thereafter, an outermost lens of the stack may be peeled off to reveal the next lens of the stack.

30 Claims, 2 Drawing Sheets



(51) **Int. Cl.**

B32B 27/08	(2006.01)
B32B 27/36	(2006.01)
B32B 27/40	(2006.01)
B32B 37/10	(2006.01)
B32B 38/10	(2006.01)

(52) **U.S. Cl.**
CPC ***B32B 27/40*** (2013.01); ***B32B 37/10*** (2013.01); ***B32B 38/10*** (2013.01); *B32B 2250/03* (2013.01); *B32B 2250/24* (2013.01); *B32B 2307/732* (2013.01); *B32B 2605/006* (2013.01)

(58) **Field of Classification Search**
CPC Y10T 428/26; Y10T 428/266; Y10T 428/269; Y10T 428/28; Y10T 428/2848; Y10T 428/2852; Y10T 428/2878; Y10T 428/2891; Y10T 428/2896; Y10T 428/31551; Y10T 428/31554; Y10T 428/31565; Y10T 428/31573; Y10T 428/31598; Y10T 428/31663; Y10T 428/31667; Y10T 428/31786; Y10T 428/31797; Y10T 428/31855; Y10T 428/31909; Y10T 428/31928; Y10T 428/31935; Y10T 428/31601; Y10T 428/31507; Y10T 428/31616; Y10T 428/31645; Y10T 428/31649; B32B 7/02; B32B 7/04; B32B 7/06; B32B 7/12; B32B 27/00; B32B 27/04; B32B 27/06; B32B 27/08; B32B 27/30; B32B 27/308; B32B 27/36; B32B 27/40; B32B 2307/40; B32B 2307/412; B32B 2307/418; B32B 2307/50; B32B 2307/514; B32B 2307/518; B32B 2307/716; B32B 2307/7163; B32B 2307/732; B32B 2307/748; B32B 2405/00; B32B 2605/00; B32B 2605/006; B32B 2605/08; B32B 27/365; B32B 17/00; B32B 17/06; B32B 17/10; B32B 17/10005; B60J 1/00; B60J 1/001; B60J 1/02; B60J 1/20; B60J 1/2094; G02B 1/00; G02B 1/04; G02B 1/041; G02B 3/00; G02B 3/02
USPC .... 428/212–215, 220, 332, 337, 339, 343, 428/354, 355 R, 355 RA, 355 EN, 428/355 AC, 355 N, 423.1, 423.3, 423.7, 428/424.2, 425.5, 446, 447, 448, 451, 428/480, 483, 500, 515, 520, 522, 412, 428/425.6, 426, 428, 429, 430, 441, 442; 296/77.1, 84.1, 90, 96.12; 359/642, 796, 359/797
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,138,086	A	11/1938	Blodjer	
2,248,331	A	7/1941	Blodjer	
2,328,687	A	9/1943	Serr	
2,339,280	A	1/1944	Madson	
2,354,415	A	7/1944	Woodard	
2,461,604	A	2/1949	Huntsman	
2,511,329	A	6/1950	Craig	
2,546,117	A	3/1951	Whelan	
2,563,125	A	8/1951	Malcom, Jr.	
2,569,715	A	10/1951	Green	
2,640,068	A	5/1953	Schaefer et al.	
2,736,109	A	2/1956	Scholl	
2,923,944	A	2/1960	Lindblom	
2,963,708	A	12/1960	Herbine et al.	
3,095,575	A	7/1963	Radov	
3,298,031	A	1/1967	Morgan	
3,475,766	A	11/1969	Raschke	
3,577,565	A	5/1971	Feldmann et al.	
3,605,115	A	9/1971	Bohner	
3,685,054	A	8/1972	Raschke	
3,774,239	A	11/1973	Kotzar	
3,785,102	A	1/1974	Amos	
3,797,042	A	3/1974	Gager	
3,810,815	A	5/1974	Welhart et al.	
3,868,293	A	2/1975	Selph	
3,937,863	A	2/1976	Moore	
3,948,662	A	4/1976	Alston et al.	
3,950,580	A	4/1976	Boudet	
3,987,569	A	10/1976	Chase	
4,063,740	A	12/1977	Mader	
4,076,373	A	2/1978	Moretti	
4,090,464	A	5/1978	Bishopp et al.	
D249,597	S	9/1978	Dillon	
4,138,746	A	2/1979	Bergmann	
D254,638	S	4/1980	Bay, Jr.	
4,204,231	A	5/1980	Permenter	
4,248,762	A	2/1981	Hornibrook et al.	
4,248,918	A	2/1981	Hornibrook et al.	
4,268,134	A	5/1981	Gulati et al.	
4,273,098	A	6/1981	Silverstein	
4,301,193	A	11/1981	Zuk	
4,332,861	A	6/1982	Franz et al.	
4,333,983	A	6/1982	Allen	
4,380,563	A	4/1983	Ayotte	
4,528,701	A	7/1985	Smith	
4,557,980	A	12/1985	William	
4,582,764	A	4/1986	Allerd et al.	
4,625,341	A	12/1986	Broersma	
4,658,515	A	4/1987	Oatman	
4,696,860	A	9/1987	Epperson	
4,701,965	A	10/1987	Landis	
4,716,601	A	1/1988	Mcneal	
4,726,074	A	2/1988	Baclit et al.	
4,729,179	A	3/1988	Quist, Jr.	
4,769,265	A	9/1988	Coburn, Jr.	
D299,767	S	2/1989	Hsin	
4,842,919	A	6/1989	David et al.	
4,850,049	A	7/1989	Landis et al.	
4,852,185	A	8/1989	Olson	
4,852,186	A	8/1989	Landis	
4,853,974	A	8/1989	Olim	
4,856,535	A	8/1989	Forbes	
4,864,653	A	9/1989	Landis	
4,867,178	A	9/1989	Smith	
4,884,296	A	12/1989	Nix, Jr.	
4,884,302	A	12/1989	Foehl	
4,889,754	A	12/1989	Vargas	
D306,363	S	2/1990	Stackhouse et al.	
4,907,090	A	3/1990	Ananian	
4,911,964	A *	3/1990	Corbo	E06B 3/285 428/354
D307,065	S	4/1990	Friedman	
4,920,576	A	5/1990	Landis	
4,934,792	A	6/1990	Tovi	
4,945,573	A	8/1990	Landis	
4,950,445	A	8/1990	Salce et al.	
D311,263	S	10/1990	Russell	
4,964,171	A	10/1990	Landis	
4,965,887	A	10/1990	Paoluccio et al.	
4,973,511	A	11/1990	Farmer et al.	
4,975,981	A	12/1990	Ray	
5,000,528	A	3/1991	Kawakatsu	
5,002,326	A	3/1991	Spicer et al.	
D318,147	S	7/1991	Russell	
5,035,004	A	7/1991	Koester	
D319,449	S	8/1991	Millar	
5,046,195	A	9/1991	Koritan	
D321,268	S	10/1991	Nix, Jr.	
5,052,054	A	10/1991	Birum	
5,067,475	A	11/1991	Posnansky	
5,071,206	A	12/1991	Hood et al.	
H1023	H	3/1992	Wiseman	

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,104,929	A	4/1992	Bilkadi
5,113,528	A	5/1992	Burke, Jr. et al.
D331,820	S	12/1992	Scanlon
D333,366	S	2/1993	Brown
5,183,700	A	2/1993	Austin
5,194,293	A	3/1993	Foster
5,201,077	A	4/1993	Dondlinger
5,206,956	A	5/1993	Olson
5,208,916	A	5/1993	Kelman
5,239,406	A	8/1993	Lynam
5,318,685	A	6/1994	O'Shaughnessy
D349,177	S	7/1994	Russell
D349,178	S	7/1994	Russell
5,327,180	A	7/1994	Hester, III et al.
D349,362	S	8/1994	Russell
5,364,671	A	11/1994	Gustafson
5,365,615	A	11/1994	Piszkin
D353,691	S	12/1994	Scanlon
D354,588	S	1/1995	Russell
D354,589	S	1/1995	Russell
5,420,649	A	5/1995	Lewis
D359,586	S	6/1995	Lofton
D361,160	S	8/1995	Russell
5,443,877	A	8/1995	Kramer et al.
D362,086	S	9/1995	Russell
5,471,036	A	11/1995	Sperbeck
5,473,778	A	12/1995	Bell
5,486,883	A	1/1996	Candido
5,510,173	A	4/1996	Pass et al.
5,512,116	A	4/1996	Campfield
5,523,132	A	6/1996	Zhang et al.
RE35,318	E	8/1996	Warman
5,544,361	A	8/1996	Fine et al.
5,553,608	A	9/1996	Reese et al.
5,555,570	A	9/1996	Bay
5,557,683	A	9/1996	Eubanks
5,584,130	A	12/1996	Perron
5,592,698	A	1/1997	Woods
5,593,786	A	1/1997	Parker et al.
5,622,580	A	4/1997	Mannheim
5,633,049	A	5/1997	Bilkadi et al.
5,668,612	A	9/1997	Hung
5,671,483	A	9/1997	Reuber
5,673,431	A	10/1997	Batty
5,687,420	A	11/1997	Chong
5,694,650	A	12/1997	Hong
5,709,825	A	1/1998	Shih
5,740,560	A	4/1998	Muoio
5,792,535	A	8/1998	Weder
5,806,102	A	9/1998	Park
5,815,848	A	10/1998	Jarvis
5,819,311	A	10/1998	Lo
5,846,659	A	12/1998	Hartmut et al.
D404,849	S	1/1999	Desy
5,885,704	A	3/1999	Peiffer et al.
5,896,991	A	4/1999	Hippely et al.
5,924,129	A	7/1999	Gill
5,937,596	A	8/1999	Leeuwenburgh et al.
5,956,175	A	9/1999	Hojnowski
5,972,453	A	10/1999	Akiwa et al.
5,991,072	A	11/1999	Solyntjes et al.
5,991,081	A	11/1999	Haaland et al.
5,991,930	A	11/1999	Sorrentino
D418,256	S	12/1999	Caruana
6,008,299	A	12/1999	Mcgrath et al.
6,049,419	A	4/2000	Wheatley et al.
6,085,358	A	7/2000	Cogan
6,173,447	B1	1/2001	Arnold
6,217,099	B1	4/2001	Mckinney et al.
6,221,112	B1	4/2001	Snider
6,237,147	B1	5/2001	Brockman
6,250,765	B1	6/2001	Murakami
6,305,073	B1	10/2001	Badders
6,347,401	B1	2/2002	Joyce
6,375,865	B1	4/2002	Paulson et al.
6,378,133	B1	4/2002	Daikuzono
6,381,750	B1	5/2002	Mangan
6,385,776	B2	5/2002	Linday
6,388,813	B1	5/2002	Wilson et al.
6,403,005	B1	6/2002	Mientus et al.
6,416,872	B1	7/2002	Maschwitz
6,432,522	B1	8/2002	Friedman et al.
6,461,709	B1	10/2002	Janssen et al.
6,469,752	B1	10/2002	Ishikawa et al.
6,491,390	B1	12/2002	Provost
6,531,180	B1	3/2003	Takushima et al.
6,536,045	B1	3/2003	Wilson et al.
6,536,589	B2	3/2003	Chang
6,555,235	B1	4/2003	Aufderheide et al.
6,559,902	B1	5/2003	Kusuda et al.
6,576,349	B2	6/2003	Lingle et al.
6,584,614	B2	7/2003	Hogg
6,592,950	B1	7/2003	Toshima et al.
6,614,423	B1	9/2003	Wong et al.
D480,838	S	10/2003	Martin
6,654,071	B2	11/2003	Chen
6,660,389	B2	12/2003	Liu et al.
6,662,371	B2	12/2003	Shin
6,667,738	B2	12/2003	Murphy
6,739,718	B1	5/2004	Jung
6,750,922	B1	6/2004	Benning
6,773,778	B2	8/2004	Onozawa et al.
6,773,816	B2	8/2004	Tsutsumi
6,777,055	B2	8/2004	Janssen et al.
6,800,378	B2	10/2004	Hawa et al.
6,838,610	B2	1/2005	De Moraes
6,841,190	B2	1/2005	Liu et al.
6,847,492	B2	1/2005	Wilson et al.
6,864,882	B2	3/2005	Newton
6,870,686	B2	3/2005	Wilson et al.
6,879,319	B2	4/2005	Cok
6,907,617	B2	6/2005	Johnson
6,911,593	B2	6/2005	Mazumder et al.
6,922,850	B1	8/2005	Arnold
6,952,950	B2	10/2005	Doe et al.
6,967,044	B1	11/2005	O'Brien
D512,797	S	12/2005	Canavan et al.
6,995,976	B2	2/2006	Richardson
7,070,837	B2	7/2006	Ross
7,071,927	B2	7/2006	Blanchard
D526,446	S	8/2006	Cowan et al.
7,097,080	B2	8/2006	Cox
7,101,810	B2	9/2006	Bond et al.
7,103,920	B1	9/2006	Otterson
7,143,979	B2	12/2006	Wood et al.
7,184,217	B2	2/2007	Wilson et al.
D541,991	S	5/2007	Lawrence
7,215,473	B2	5/2007	Fleming
7,226,176	B1	6/2007	Huang
7,238,401	B1	7/2007	Dietz
7,311,956	B2	12/2007	Pitzen
D559,442	S	1/2008	Regelbrugge et al.
7,344,241	B2	3/2008	Baek
7,351,470	B2	4/2008	Draheim et al.
D569,557	S	5/2008	Cho
7,389,869	B2	6/2008	Mason, Jr.
7,410,684	B2	8/2008	Mccormick
7,425,369	B2	9/2008	Oakey et al.
D586,052	S	2/2009	Elias
7,495,895	B2	2/2009	Carnevali
7,597,441	B1	10/2009	Farwig
7,629,052	B2	12/2009	Brumwell
7,631,365	B1	12/2009	Mahan
7,663,047	B2	2/2010	Hanuschak
7,709,095	B2	5/2010	Persoone et al.
7,722,921	B2	5/2010	Shimoda et al.
7,727,615	B2	6/2010	Kato et al.
7,752,682	B2	7/2010	Vanderwoude et al.
7,812,077	B2	10/2010	Borade et al.
7,858,001	B2	12/2010	Qin et al.
7,937,775	B2	5/2011	Manzella, Jr. et al.
7,957,524	B2	6/2011	Chipping
8,024,818	B1	9/2011	Davenport
8,044,942	B1	10/2011	Leonhard et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,261,375 B1 9/2012 Reaux
8,292,347 B1 * 10/2012 Drake B60J 1/2094 160/370.21
8,294,843 B2 10/2012 Hollaway
8,361,260 B2 1/2013 Wilson et al.
D683,077 S 5/2013 Klotz et al.
8,455,105 B2 6/2013 Hobeika et al.
D692,187 S 10/2013 Isobe
D692,189 S 10/2013 Isobe
8,567,596 B1 10/2013 Mason, Jr.
8,693,102 B2 4/2014 Wilson et al.
8,889,801 B2 11/2014 Liao et al.
8,974,620 B2 3/2015 Wilson et al.
D726,378 S 4/2015 Wako
8,999,509 B2 4/2015 Port et al.
9,023,162 B2 5/2015 Mccormick et al.
9,104,256 B2 8/2015 Wilson et al.
9,128,545 B2 9/2015 Wilson et al.
9,150,763 B2 10/2015 Lopez et al.
9,161,858 B2 10/2015 Capers et al.
9,170,415 B2 10/2015 Mansuy
9,274,625 B2 3/2016 Wilson et al.
9,295,297 B2 3/2016 Wilson
D759,900 S 6/2016 Cummings et al.
9,442,306 B1 * 9/2016 Hines G06F 3/00
9,471,163 B2 10/2016 Wilson et al.
9,526,290 B2 12/2016 Wilson
9,575,231 B2 2/2017 Chu et al.
D781,507 S 3/2017 Huh
D781,508 S 3/2017 Huh
9,629,407 B2 4/2017 Foster
9,671,622 B1 6/2017 Vetrini et al.
9,726,940 B2 8/2017 Tomiyasu
D805,256 S 12/2017 Yang
9,905,297 B2 2/2018 Best
D815,190 S 4/2018 Dellemann
9,968,155 B2 5/2018 Wilson
10,070,678 B2 9/2018 Wilson
10,165,819 B2 1/2019 Klotz et al.
10,226,095 B2 3/2019 Wilson
10,227,501 B2 3/2019 Hwang et al.
D849,240 S 5/2019 Guo et al.
D850,256 S 6/2019 Ryszawy
10,321,731 B2 6/2019 Wilson
10,345,934 B2 7/2019 Wilson et al.
10,427,385 B2 10/2019 Wilson et al.
10,520,756 B2 12/2019 Gallina et al.
D879,384 S 3/2020 Sato
D882,182 S 4/2020 Fekete
10,620,670 B2 4/2020 Wilson et al.
10,687,569 B1 6/2020 Mcdirmid
10,716,986 B2 7/2020 Winter et al.
D907,299 S 1/2021 Brown, II et al.
D907,300 S 1/2021 Brown, II et al.
D925,129 S 7/2021 Wilson
D925,834 S 7/2021 Babin et al.
11,141,959 B2 10/2021 Wilson et al.
11,147,323 B1 10/2021 Wilson
11,307,329 B1 4/2022 Wilson
2001/0035936 A1 11/2001 Maisnik
2002/0025441 A1 2/2002 Hieda et al.
2002/0036362 A1 3/2002 Chigira et al.
2002/0101411 A1 8/2002 Chang
2002/0109922 A1 8/2002 Wilson et al.
2002/0114934 A1 8/2002 Liu et al.
2002/0122925 A1 9/2002 Liu et al.
2002/0159159 A1 10/2002 Wilson et al.
2002/0195910 A1 12/2002 Hus et al.
2003/0012936 A1 1/2003 Draheim et al.
2003/0087054 A1 5/2003 Janssen et al.
2003/0110613 A1 6/2003 Ross
2004/0004605 A1 1/2004 David
2004/0109096 A1 6/2004 Anderson et al.
2004/0121105 A1 6/2004 Janssen et al.
2004/0139530 A1 7/2004 Yan
2004/0202812 A1 10/2004 Congard et al.
2004/0227722 A1 11/2004 Friberg et al.
2004/0238690 A1 12/2004 Wood et al.
2004/0246386 A1 12/2004 Thomas et al.
2004/0258933 A1 12/2004 Enniss et al.
2005/0002108 A1 1/2005 Wilson et al.
2005/0015860 A1 1/2005 Reaux
2005/0133035 A1 6/2005 Yahiaoui et al.
2005/0186415 A1 8/2005 Mccormick et al.
2005/0188821 A1 9/2005 Yamashita et al.
2005/0200154 A1 9/2005 Barbee et al.
2005/0249957 A1 11/2005 Jing et al.
2005/0260343 A1 11/2005 Han
2006/0024494 A1 2/2006 Amano et al.
2006/0052167 A1 3/2006 Boddicker et al.
2006/0056030 A1 3/2006 Fukuda et al.
2006/0057399 A1 3/2006 Persoone et al.
2006/0114245 A1 6/2006 Masters et al.
2006/0138694 A1 6/2006 Biernath et al.
2006/0158609 A1 7/2006 Heil
2006/0177654 A1 8/2006 Shoshi
2006/0204776 A1 9/2006 Chen et al.
2006/0254088 A1 11/2006 Mccormick
2006/0285218 A1 12/2006 Wilson et al.
2007/0019300 A1 1/2007 Wilson et al.
2007/0181456 A1 8/2007 Kusuda et al.
2007/0211002 A1 9/2007 Zehner et al.
2007/0212508 A1 9/2007 Mase
2007/0229962 A1 10/2007 Mason
2007/0234592 A1 10/2007 Crates
2007/0234888 A1 10/2007 Rotolo De Moraes
2007/0286995 A1 12/2007 Li et al.
2008/0014446 A1 1/2008 Donea et al.
2008/0030631 A1 2/2008 Gallagher
2008/0030675 A1 2/2008 Dillon
2008/0055258 A1 3/2008 Sauers
2008/0118678 A1 5/2008 Huang et al.
2008/0151177 A1 6/2008 Wang
2008/0160321 A1 7/2008 Padiyath et al.
2008/0176018 A1 7/2008 Enniss et al.
2008/0231979 A1 9/2008 Chen
2008/0286500 A1 11/2008 Sussner et al.
2008/0292820 A1 11/2008 Padiyath et al.
2009/0011205 A1 1/2009 Thiel
2009/0026095 A1 1/2009 Lofland et al.
2009/0054115 A1 2/2009 Horrdin et al.
2009/0086415 A1 4/2009 Chipping
2009/0087655 A1 4/2009 Yamada et al.
2009/0105437 A1 4/2009 Determan et al.
2009/0119819 A1 5/2009 Thompson
2009/0181242 A1 7/2009 Enniss et al.
2009/0233032 A1 9/2009 Craig
2009/0239045 A1 9/2009 Kato et al.
2009/0239048 A1 9/2009 Sugihara et al.
2010/0026646 A1 2/2010 Xiao et al.
2010/0033442 A1 2/2010 Kusuda et al.
2010/0102197 A1 4/2010 Mcintyre
2010/0122402 A1 5/2010 Tipp
2010/0146679 A1 6/2010 Heil
2010/0238119 A1 9/2010 Dubrovsky et al.
2010/0245273 A1 9/2010 Hwang et al.
2010/0270189 A1 10/2010 Pedersen et al.
2011/0007388 A1 1/2011 Wilson et al.
2011/0010994 A1 1/2011 Wilson et al.
2011/0012841 A1 1/2011 Lin
2011/0013273 A1 1/2011 Wilson et al.
2011/0014481 A1 1/2011 Wilson et al.
2011/0035936 A1 2/2011 Lee
2011/0052864 A1 3/2011 Son
2011/0097574 A1 4/2011 Faldysta et al.
2011/0119801 A1 5/2011 Wright
2011/0165361 A1 7/2011 Sherman et al.
2011/0168261 A1 7/2011 Welser et al.
2011/0267793 A1 11/2011 Cohen et al.
2011/0271497 A1 11/2011 Suh et al.
2011/0277361 A1 11/2011 Nichol et al.
2011/0279383 A1 11/2011 Wilson et al.
2012/0003431 A1 1/2012 Huang
2012/0030095 A1 2/2012 Marshall et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0047614 A1 3/2012 Choi
2012/0070603 A1 3/2012 Hsu
2012/0081792 A1 4/2012 Neuffer
2012/0137414 A1 6/2012 Saylor
2012/0180204 A1 7/2012 Hawkins
2012/0183712 A1 7/2012 Leonhard et al.
2012/0188743 A1 7/2012 Wilson et al.
2012/0200816 A1 8/2012 Krasnov et al.
2012/0291173 A1 11/2012 Gleason et al.
2013/0045371 A1 2/2013 O'Donnell
2013/0089688 A1 4/2013 Wilson et al.
2013/0141693 A1 6/2013 McCabe et al.
2013/0145525 A1 6/2013 Arenson et al.
2013/0222913 A1 8/2013 Tomoda et al.
2013/0247286 A1 9/2013 Vanderwoude et al.
2013/0293959 A1 11/2013 Mcdonald
2014/0020153 A1 1/2014 Romanski et al.
2014/0050909 A1 2/2014 Choi et al.
2014/0220283 A1 8/2014 Wilson et al.
2014/0259321 A1 9/2014 Arnold
2015/0033431 A1 2/2015 Hofer Kraner et al.
2015/0131047 A1 5/2015 Saylor et al.
2015/0234209 A1 8/2015 Miyamoto et al.
2015/0294656 A1 10/2015 Hanuschak
2015/0309609 A1 10/2015 Wilson et al.
2015/0349147 A1 12/2015 Xi et al.
2015/0359675 A1 12/2015 Wilson
2016/0023442 A1 1/2016 Faris
2016/0050990 A1 2/2016 Hayes
2016/0073720 A1 3/2016 Niedrich
2016/0231834 A1 8/2016 Hardi
2016/0259102 A1 9/2016 Taka
2016/0271922 A1 9/2016 Uzawa et al.
2016/0291543 A1 10/2016 Saito
2016/0318227 A1 11/2016 Kim et al.
2017/0079364 A1 3/2017 Paulson
2017/0129219 A1 5/2017 Uebelacker et al.
2017/0173923 A1 6/2017 Davis et al.
2017/0208878 A1 7/2017 Kakinuma et al.
2017/0232713 A1 8/2017 Mannheim Astete et al.
2017/0281414 A1 10/2017 Wilson
2017/0299898 A1 10/2017 Gallina et al.
2017/0318877 A1 11/2017 Yahiaoui et al.
2018/0029337 A1 2/2018 Wilson et al.
2018/0042324 A1 2/2018 King
2018/0052334 A1 2/2018 Repko
2018/0094164 A1 4/2018 Ito et al.
2018/0148578 A1 5/2018 Ohta et al.
2018/0161208 A1 6/2018 Huh
2018/0236753 A1 8/2018 Wykoff, II et al.
2018/0295925 A1 10/2018 Gagliardo et al.
2018/0338550 A1 11/2018 Boulware et al.
2019/0021430 A1 1/2019 Elliott
2019/0037948 A1 2/2019 Romanski et al.
2019/0118057 A1 4/2019 Winter et al.
2019/0209912 A1 7/2019 Isserow et al.
2019/0212474 A1 7/2019 Le Quang et al.
2020/0100657 A1 4/2020 Lee et al.
2020/0115519 A1 4/2020 Phillips et al.
2020/0124768 A1 4/2020 Wilson
2020/0154808 A1 5/2020 Inouye
2020/0178622 A1 6/2020 Jascomb et al.
2020/0281301 A1 9/2020 Wynalda, Jr.
2020/0310494 A1* 10/2020 Ahn B32B 17/10
2021/0030095 A1 2/2021 Reicher
2021/0298380 A1 9/2021 Brown, II et al.
2021/0298390 A1 9/2021 Sup, IV et al.
2021/0307425 A1 10/2021 Keim
2021/0315291 A1 10/2021 Votolato et al.
2021/0318553 A1 10/2021 Gharabegian
2021/0321692 A1 10/2021 Wilson
2021/0321693 A1 10/2021 Wilson et al.
2021/0329999 A1 10/2021 Ackerman
2021/0368886 A1 12/2021 Swart et al.
2021/0386155 A1 12/2021 Rose
2022/0015472 A1 1/2022 Boza
2023/0106407 A1* 4/2023 Arima C09D 175/04
428/35.8

FOREIGN PATENT DOCUMENTS

DE 3637188 A1 5/1988
DE 19808535 A1 9/1999
DE 202004010014 U1 4/2005
DE 202020101562 U1 4/2020
DE 202020101794 U1 4/2020
EP 192075 A2 8/1986
EP 671258 A2 9/1995
EP 1471415 A2 10/2004
EP 3157480 A1 4/2017
GB 2310862 A 9/1997
JP 61017860 A 1/1986
JP S6117860 A 1/1986
JP 62053832 A 3/1987
JP 04314537 A 11/1992
JP 06143496 A 5/1994
JP 07021456 A 1/1995
JP 10167765 A 6/1998
JP 2002328613 A 11/2002
JP 2012183822 A 9/2012
JP 2014032222 A 2/2014
JP 2015128896 A 7/2015
JP 6767596 B1 * 10/2020 .... B32B 27/08
KR 20120001292 A 1/2012
TW 200700793 A 1/2007
TW 201027992 A 7/2010
WO 0024576 A1 5/2000
WO 03052678 A1 6/2003
WO 2015009114 A1 1/2015
WO 2015091425 A1 6/2015
WO 2015093413 A1 6/2015
WO 2015195814 A1 12/2015
WO 2019006151 A1 1/2019
WO 2019055267 A1 3/2019
WO WO-2021176316 A1 * 9/2021 .... B29C 48/21

OTHER PUBLICATIONS

www.wikipedia.org. "Infrared", Jul. 2009, 12 pages.

www.wikipedia.org. "PET Film (biaxially oriented)", Jul. 2009, 4 pages.

PCT International Application No. PCT/US99/25128 with International Search Report, Date of Completion Jan. 18, 2000, 54 Pages.

English translation of TW201027992, "Monitor Protection Device for a Flat Panel Display", 11 pgs.

Pulse Racing Innovations, EZ Tear Universal Single Pull Tearoff Ramp, webpage <https://www.pulseracinginnovations.com>, Dec. 30, 2020, 6 pages.

PCT International Search Report and Written Opinion for International Application No. PCT/US20/24639, Jun. 11, 2020, 13 pages.

PCT International Search Report and Written Opinion for International Application No. PCT/US2020/049919; Nov. 27, 2020.

Tian-Chi Chang, Xun Cao, Shan-Hu Bao, Shi=Dong Ji, Hong-Jie Luo, Ping Jin; "Review on Thermochromic Vanadium Dioxide Based Smart Coatings: From Lab to Commercial Application"; Dec. 16, 2017.

PCT International Search Report and Written Opinion for International Application No. PCT/US2020/062230; Feb. 3, 2021.

"Anti-reflective coating," Wikipedia, last updated Jul. 13, 2017 by Andy Dingley, <https://en.m.wikipedia.org/wiki/Anti-reflective_coating>.

"Monotonic function," Wikipedia, accessed May 24, 2017, <https://en.wikipedia.org/wiki/Monotonic_function>.

"Thin Film," Wikipedia, last updated Jun. 20, 2017, <https://en.wikipedia.org/wiki/Thin_film>.

"Tips to Get Quality Anti-Reflection Optical Coatings," Penn Optical Coatings, accessed May 24, 2017, <http://www.pennoc.com/tipsgetqualityantireflectionopticalcoatings/>.

(56) **References Cited**

OTHER PUBLICATIONS

Langlet, M., "Antireflective Films", from Chapter 15 of Handbook of Sol-Gel Science and Technology Processing Characterization and Applications, copyright 2005, pp. 332-334, 337, 339-341., taken from website <https://books.google.com/books?id=i9swy1D2HxIC&Ipg=PA339&dq=AR%20thick%20film%20coatings&pg=PA339#v=onepage&q=AR%20thick%20film%20coatings&f=false>.
Li, H.-M. et al., "Influence of weight ratio in polymer blend film on the phase separation structure and its optical properties", The European Physical Journal Applied Physics, 45, 20501, published Jan. 31, 2009, EDP Sciences, 4 pages.
MDS Nordion, "Gamma Compatible Materials," Datasheet, Aug. 2007, 4 pages, <https://ab-div-bdi-bl-blm.web.cern.ch/Radiation/Gamma_Compatible_Materials_List_company.pdf>, retrieved on Sep. 29, 2021.
Zhang, Xin_Xiang et al., Abstract of "One-step sol-gel preparation of PDMS-silica ORMOSILs as environment-resistant and crack-free thick antireflective coatings," Journal of Materials Chemistry, Issue 26, 2012, <http://pubs.rsc.org/en/content/articlelanding/2012/m/c2jm31005h#!divAbstract>.
PCT International Search Report and Written Opinion for International Application No. PCT/US2017/044438, dated Oct. 23, 2017, 12 pages.
Chemical Book, "Benzophenone", https://www.chemicalbook.com/Chemical ProductProperty_EN_CB57 44679.htm, available at least as of 2017, accessed on line on Dec. 15, 2021 (Year: 2017).
Chemical Book, "Polymethylhydrosiloxane", https://www.chemicalbook.com/Chemical ProductProperty_EN_ CB3694969. htm, available at least as of 2017, accessed online on Dec. 15, 2021 (Year: 2017).
Guide Chem, "UV Stabilizer", https://wap.guidechem.com/trade/uv-stabilizer-uv-absorber-ligh-id3578792.html, available at least as of 2018, accessed online on Dec. 15, 2021 (Year: 2018).
Hostaphan RBB biaxially oriented film data sheet (Year: 2011).
PCT International Search Report and Written Opinion for International Application No. PCT/US2020/024639; Jun. 11, 2020.
PCT International Search Report and Written Opinion for International Application No. PCT/US2021/026165, dated Jul. 9, 2021, 10 pages.
PCT International Search Report and Written Opinion for International Application No. PCT/US21/20421, May 20, 2021, 8 pages.
Wiseman, Sr., United States Statutory Invention Registration No. H1023, published Mar. 3, 1992, 7 pages.
Chemical Book, Bis(1,2,2,6,6-pentamethyl-4-piperidyl) sebacate, available online at least as of 2017, https://www.chemicalbook.com/ChemicalProductProperty_EN_CB8121619.htm, accessed online Mar. 15, 2022 (Year: 2017).
Pearson Dental, "UV Protection Face Shields", https://www.pearsondental.com/catalog/subcat_thumb.asp?majcatid=750&catid=l0149, available online at least as of Jan. 27, 2021 per Internet Archive, accessed online on Sep. 15, 2021. (Year: 2021).
Patent Cooperation Treaty, International Search Report and Written Opinion for International Application No. PCT/US2022/031823, mailed Jul. 14, 2022, 11 pages.
Racing Optics, Inc. v. *Aevoe Corp. dba Moshi*; Case 2:15-cv-01774-RCJ-VCF; "Answer to Aevoe's Counterclaims—Jury Trial Demanded"; Nov. 2, 2015; 15 pages.
Gregory Brower et al.; "Complaint for Patent Infringement"; Sep. 15, 2015; 15 pages.
Jeffrey A. Silverstri et al.; "Answer to Complaint for Patent Infringement"; Oct. 7, 2015; 59 pages.
United States Patent and Trademark Office; Office Action for U.S. Appl. No. 15/090,681; Aug. 26, 2016; 8 pages.
List of References for U.S. Appl. No. 15/090,681; Receipt date Jun. 30, 2016; 3 pages.
List of References for U.S. Appl. No. 15/090,681; Receipt date Apr. 27, 2016; 4 pages.
Examiner's search strategy and results for U.S. Appl. No. 15/090,681; Aug. 21, 2016; 2 pages.
Aevoe Corp. v. *Racing Optics, Inc.*; Case No. IPR2016-01164; Petition for Inter Partes Review of U.S. Pat. No. 9,104,256 (including Exhibits 1001-1011 and Petitioner Power of Attorney Pursuant to 37 C.F.R. 42. 10(b) for Petition for Inter Partes Review); Jun. 21, 2016.
Aevoe Corp. v. *Racing Optics, Inc.*; Case No. IPR2016-01165; Petition for Inter Partes Review of U.S. Pat. No. 9,128,545(including Exhibits 1001-1006 and Petitioner Power of Attorney Pursuant to 37 C.F.R. 42. 10(b) for Petition for Inter Partes Review); Jun. 21, 2016.
Aevoe Corp. v. *Racing Optics, Inc.*; Case No. IPR2016-01166; Petition for Inter Partes Review of U.S. Pat. No. 9,274,625 (including Exhibits 1001-1011 and Petitioner Power of Attorney Pursuant to 37 C.F.R. 42. 10(b) for Petition for Inter Partes Review); Jun. 21, 2016.
Exhibit 1—Invalidity Contentions re: '545 Patent Under LPR 1-8(b)-(d); at least as early as Jul. 1, 2016.
Exhibit 2—Invalidity Contentions re: '256 Patent Under LPR 1-8(b)-(d); at least as early as Jul. 1, 2016.
Exhibit 3—Invalidity Contentions re: '620 Patent Under LPR 1-8(b)-(d); at least as early as Jul. 1, 2016.
Exhibit 4—Invalidity Contentions re: '625 Patent Under LPR 1-8(b)-(d); at least as early as Jul. 1, 2016.
Exhibit 1002—U.S. Pat. No. 5,364,671 to Gustafson; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-6.
Exhibit 1004—U.S. Pat. No. 7,351,470 to Draheim et al; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-15.
Exhibit 1001—U.S. Pat. No. 8,974,620 to Wilson et al.; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-15.
Exhibit 1003—U.S. Pat. No. 6,250,765 to Murakami; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; p. 1-8.
Exhibit 1005—U.S. Pat. No. 7,957,524 to Chipping; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2017; pp. 1-20.
Aevoe Corp., Racing Optics, Inc.; Petition for Inter Partes Review; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-55.
Exhibit 1006—Japanese Application No. JP 2002-328613 to Kitaguchi Translation; IPR2016-01745; at least as early as Sep. 7, 2016; pp. 1-10.
Exhibit 1009—U.S. Appl. No. 13/838,311; Interview Summary; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; p. 1-3.
Exhibit 1010—U.S. Appl. No. 15/838,311; Notice of Allowance; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-8.
Aevoe Corp. v. *Racing Optics, Inc.*; Declaration of Darran Cairns; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-32.
Aevoe Corp. v. *Racing Optics, Inc.*; Petitioner's Power of Attorney; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-3.
Exhibit 1007—U.S. Appl. No. 13/838,311; Response to Office Action; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; p. 1-19.
Exhibit 1008—U.S. Appl. No. 13/838,311; Response and Request for Continued Examination; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-21.
Aevoe Corp. v. *Racing Optics, Inc.*; Mandatory Notices; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-4.
Aevoe Corp. v. *Racing Optics, Inc.*;Power of Attorney; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 7, 2016; pp. 1-4.
Aevoe Corp. v. *Racing Optics, Inc.*; Notice of Filing Date; Case IPR2016-01745; Inter Partes Review of U.S. Pat. No. 8,974,620; at least as early as Sep. 6, 2016; p. 1-5.

(56) **References Cited**

OTHER PUBLICATIONS

Aevoe Corp. v. *Racing Optics, Inc.*; Decision; Case IPR2016-01164; Inter Partes Review of U.S. Pat. No. 9,104,256; at least as early as Nov. 7, 2016; p. 1-24.
Aevoe Corp. v. *Racing Optics, Inc.*; Decision; Case IPR2016-01166; Inter Partes Review of U.S. Pat. No. 9,274,625; at least as early as Nov. 7, 2016; p. 1-23.
Aevoe Corp. v. *Racing Optics, Inc.*; Decision; Case IPR2016-01165; Inter Partes Review of U.S. Pat. No. 9,128,545; at least as early as Nov. 7, 2016; p. 1-25.
Settlement and License Agreement, Dec. 21, 2007, 28 pgs.
United States Patent and Trademark Office; Office Action dated Dec. 21, 2016 pertaining to U.S. Appl. No. 15/090,681, filed Apr. 5, 2016; 8 pages.
PCT Search Report and Written Opinion for US2020/016245 (Apr. 28, 2020).
Professional Plastics (http://www.professionalplastics.com/MelinexPETFilmDupont) 2012.
Whitney, Frank D., Preliminary Injunction, Aug. 21, 2007, 5 pgs.
Higgins, John P., Answer and Counterclaims to First Amended Complaint, Sep. 4, 2007, 27 pgs.
Ballato, John, Expert Report of John Ballato, Ph.D., Nov. 12, 2007, 5 pgs.
Russell, Geoffrey A., Rebuttal Report of Geoffrey A. Russell, Ph.D., on issues raised in the Export Report of John Ballato, Ph.D., Nov. 21, 2007, 15 pgs.
Higgins, John P., Defendants' Second Supplement to Its Response to Plaintiffs' First Set of Interrogatories, Dec. 7, 2007, 25 pgs.
Barnhardt, John J. III, Redacted Version Defendants' Memorandum in Support of Motion for Partial Summary Judgment, Dec. 3, 2007, 36 pgs.
Higgins, John P., Defendants' Second Supplement to its Response to Plaintiffs' First Set of Interrogatories, Dec. 7, 2007, 26 pgs.
Whitney, Frank D., Consent Judgment Order, Jan. 3, 2008, 5 pgs.
Ballato, John, Supplemental Expert Report of John Ballato, Ph.D., Nov. 19, 2007, 10 pgs.
Moore, Steven D., Plaintiffs' Motion to Strike Defendants' New and Untimely Invalidity Theory, Dec. 19, 2007, 3 pgs.
Moore, Steven D., Plaintiffs' Brief in Support of Motion to Strike Defendants' New and Untimely Invalidity Theory, Dec. 19, 2007, 10 pgs.
Barnhardt, John J. III, Notice Pursuant to 35 U.S.C. 282, Dec. 18, 2007, 3 pgs.
Office Action for Canadian Patent Application No. 2,952,436; Jul. 8, 2020.
Prosecution History of U.S. Re-Examination Application No. 95/002,073 titled Touch Screen Protector; pp. 1-1,980.
www.store.moshimode.com; "iVisor AG for iPad 2 Black"; 2004-2010.
Defendant's Motion for Summary Judgment; Oct. 25, 2013; pp. 1-31.
Jake Gaecke; "Appletell Reviews the iVisor for iPad"; www.appletell.com; Sep. 15, 2010 at 12:32 p.m. www.technologytell.com/apple/60407/appletell-reviews-ag-for-ipad/; 2 pages.
www.nushield.com/technology.php; "What Makes NuShield Screen Protectors Superior", 2 pages.
www.spigen.com; "Something You Want"; 2 pages.
www.zagg.com; "Apple iPad 2 (Wi-Fi 3G) Screen Protector"; 2 pages.
www.gadgetguard.com; "Invisible Gadget Guard, the Original"; 1 page.
www.incipotech.com; "Protect Your iPhone 4 with Screen Protectors from Incipo"; 3 pages.
www.store.moshimonde.com; "iVisor AG iPad Screen Protector"; Jul. 2010; 7 pages.
www.store.moshimonde.com; "iVisor XT Crystal Clear Protector for iPad"; Aug. 2010; 3 pages.
www.store.moshimonde.com; "iVisor AG for iPad 2 Black"; Mar. 2011; 5 pages.
www.store.moshimonde.com; "iVisor AG for iPad 2 White"; Mar. 2011; 3 pages.
www.store.moshimonde.com; "iVisor AG for iPhone 4/4S Black"; Nov. 2010; 5 pages.
www.store.moshimonde.com; "iVisor AG for iPhone 4/4S White"; May 2010; 4 pages.
Dictionary.com (http://dictionary.reference.com) 2012.
Racing Optics, Inc. v. *Aevoe, Inc., d/b/a/ Moshi*; Case No. 15-cv-017744-JCM-VCF; Aevoe's Initial Disclosure Non-Infringement, Invalidity and Unenforceability Contentions (Redacted) dated Jan. 7, 2016.
Defendant Aevoe Corp.'s Non-Infringement Contentions and Responses to Racing Optic's Disclosure of Asserted Claims and Infringement Contentions (U.S. Pat. No. 9,128,545) dated Jan. 7, 2016.
Defendant Aevoe Corp.'s Non-Infringement Contentions and Responses to Racing Optic's Disclosure of Asserted Claims and Infringement Contentions (U.S. Pat. No. 9,104,256) dated Jan. 7, 2016.
Defendant Aevoe Corp.'s Non-Infringement Contentions and Responses to Racing Optic's Disclosure of Asserted Claims and Infringement Contentions (U.S. Pat. No. 8,974,620) dated Jan. 7, 2016.
I-Blason LLC v. *Aevoe, Inc. and Aevoe Corp.*; Case IPR2016-TBA; Petition for Inter Partes Review of U.S. Pat. No. 8,044,942 (including Exhibits 1001-1019).
Dupont Teijin Films, "Mylar Polyester Film—Optical Properties", Jun. 2003, 2 pages.
https://en.wikipedia.org/wiki/Black_body, "Black Body", Jul. 2009, 11 pages.
https://en.wikipedia.org/wiki/Infrared, "Infrared", Jul. 2009, 12 pages.
https://en.wikipedia.org/wiki/BoPET, "PET Film (biaxially oriented)", Jul. 2009, 4 pages.
Instashield LLC, Bionic Wrench® Inventor Creates Low-Cost Face Shield For Masses, Apr. 15, 2020, 3 pages.
Tom Zillich, Surrey manufacturer hopes to hit home run with face shield that clips to baseball cap, Apr. 29, 2020, 3 pages.
Opentip, Opromo Safety Face Shield Visor for Adult Kids, Protective Cotton Hat with Removable PVC Face Cover <https://www.opentip.com/product.php?products_id=11699030>, May 5, 2020, 3 pages.
Hefute, Hefute 5 PCS Protective Face Cover with Shield Comfortable Full Protection Face Compatible with Glasses Anti-Droplet Anti-Pollution and Windproof Transparent Safety Face Cover with Shield(Style B) <https://www.amazon.com/dp/B086GSG8DH/ref=sspa_dk_detail_9?psc=1&pd_rd_i=B086GSG8DH&pd_rd_w=Ocdm2&pf_rd_p=48d372c1-7e1-4b8b-9d02-4bd86f5158c5&pd_rd_wg=qkB2b&pf_rd_r=M%E2%80%A6>, May 6, 2020, 7 pages.
Geanbaye, Geanbaye Safety Full Face Shield Cap Detachable Baseball Cap Anti-Saliva Anti-Spitting Eye Protective Hat Windproof Dustproof <https://www.amazon.com/dp/B086DV32B8/ref=sspa_dk_detail_8?psc=1&pd_rd_i=B086DV32B8&pd_rd_w=MwjfT&pf_rd_p=48d372c1-7e1-4b8b-9d02-4bd86f5158c5&pd_rd_wg=pxuOs&pf_rd_r=PNDA%E2%80%A6>, May 5, 2020, 8 pages.
Leigh Buchanan, These 2 Companies Are Making Face Shields for Everyone <https://www.inc.com/leigh-buchanan/face-shields-coronavirus-protection-open-source.html>, May 6, 2020, 8 pages.
Brim Shield, photographs, Apr. 21, 2020, 1 pages.
Hatshield, Shield Yourself With The Hatshield <https://www.hatshield.com/?gclid=CjwKCAjwp-X0BRAFEiwAheRui1u89v_3URuiwEVvBRGa9TaEfWoZVMJXRkWsZgPTUw-0fHJ5HD-8uhoCc84QAvD_BwE>, Apr. 17, 2020, 11 pages.
Eli N. Perencevich, Moving Personal Protective Equipment Into the Community Face Shields and Containment of COVID-19, Apr. 29, 2020, 2 pages.
Chang, Tian-Ci; Cao, Xun; Bao, Shan-Hu; Ji, Shi-Dong; Luo, Hong-Jie; Jin, Ping; Review of Thermochromic Vanadium Dioxide Based Smart Coatings: From Lab to Commercial Application; Dec. 16, 2017.
Saudi Basic Industries Corporation (SABIC); "The Department of Transportation [DOT] Guidebook"; Oct. 2016.
Hostaphan RBB, "Transparent, Temperature Stable Polyester Film for Cooking & Roasting Bags" Jul. 2016.
Hostaphan Win, "White, Long-Term Stable, Thermally Stable Polyester Film for PV Back Sheet Laminates"; Jul. 2016.

(56) **References Cited**

OTHER PUBLICATIONS

PCT Search Report & Written Opinion for PCT/US2019/054565 (Dec. 20, 2019).

PCT Search Report & Written Opinion for PCT/US2015/036248 (Sep. 16, 2015).

"Declaration of Jerome Aho"; Filed Aug. 3, 2007; Case 3:07-cv-00221-FDW-DCK; Includes: Exhibit A, Nascar Postcard (1 page), Exhibit B, 50th Anniversary Nascar letter sent Jan. 7, 1998 (1 page), and Exhibit C, Front page of "The Official Nascar Preview and Press Guide" (1 page); 9 pages.

Racing Optics, Inc. v. *David Leon O'Neal, Edward M. Wallace and Clear View Racing Optics, LLC*; Case 3:07 CV 221; Includes: Exhibit A, Wilson et al. U.S. Pat. No. 6,847,492; and Exhibit B, Wilson et al. U.S. Pat. No. 7,184,217; 34 pages.

International Search Report; International Application No. PCT/US99/95128; Date of Completion: Jan. 18, 2000; 54 pages.

International Search Report; International Application No. PCT/US02/10971; Date of Completion: Nov. 20, 2002; 3 pages.

International Search Report; International Application No. PCT/US03/16284; Date of Completion: Mar. 9, 2004; 3 pages.

European Search Report for Application No. 15809930.9-107 / 3157480 (Dec. 15, 2017).

Canadian Office Action for Application Serial No. 2,952,436 (Nov. 15, 2019).

Canadian Office Action for Application Serial No. 2,952,436 (May 3, 2019).

Australian Examination Report for Application Serial No. 2015277196 (Oct. 18, 2018).

www.wikipedia.org, Refractive Index, Oct. 31, 2014.

* cited by examiner

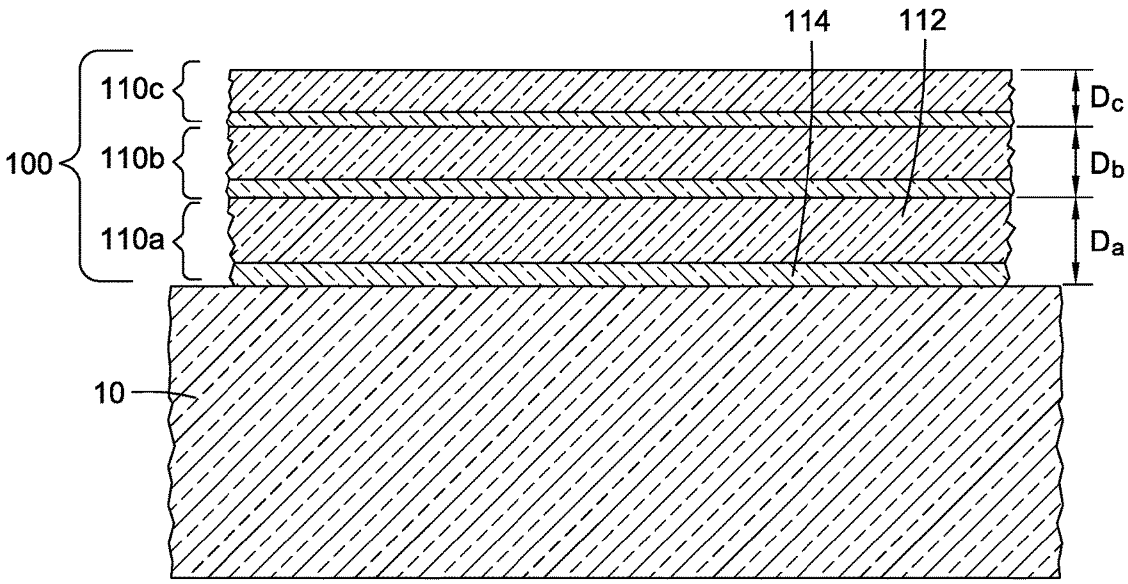

114
112
110c
110b
110a
100
10
D_c
D_b
D_a

FIG. 1

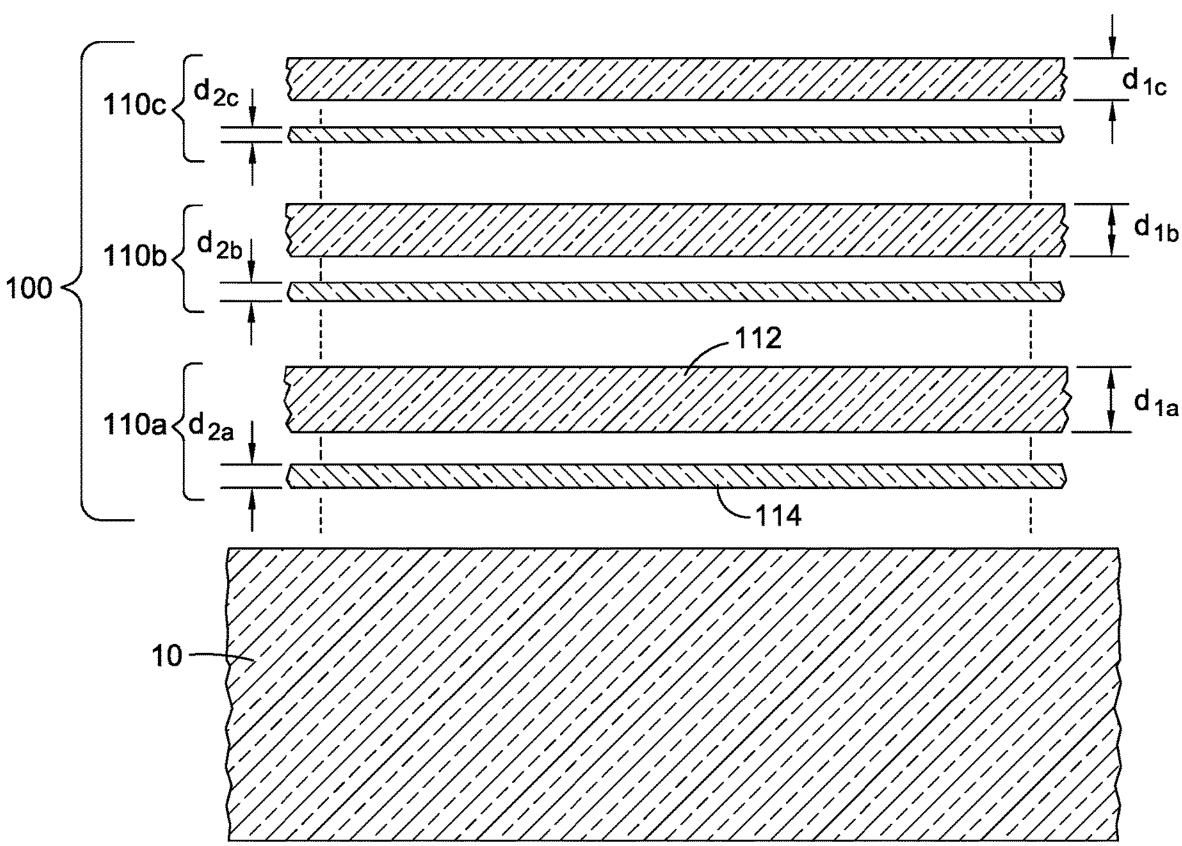

100
110c
110b
110a
d_{2c}
d_{2b}
d_{2a}
d_{1c}
d_{1b}
d_{1a}
112
114
10

FIG. 2

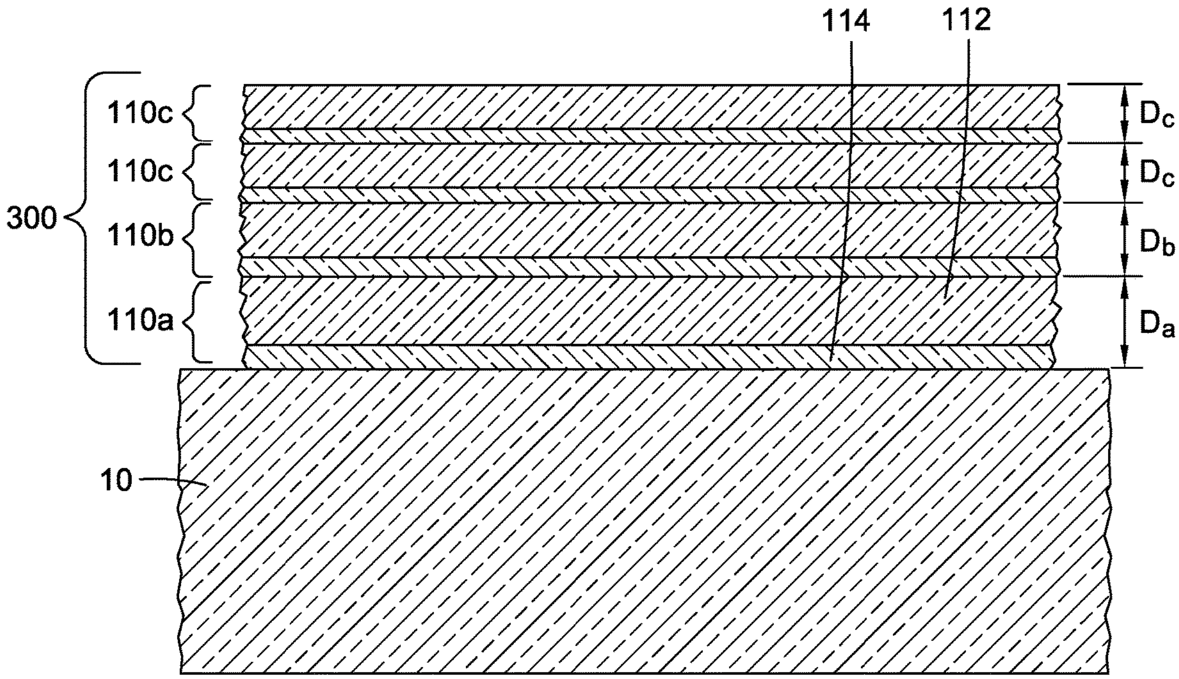

114
112
110c
110c
300
110b
110a
Dc
Dc
Db
Da
10

FIG. 3

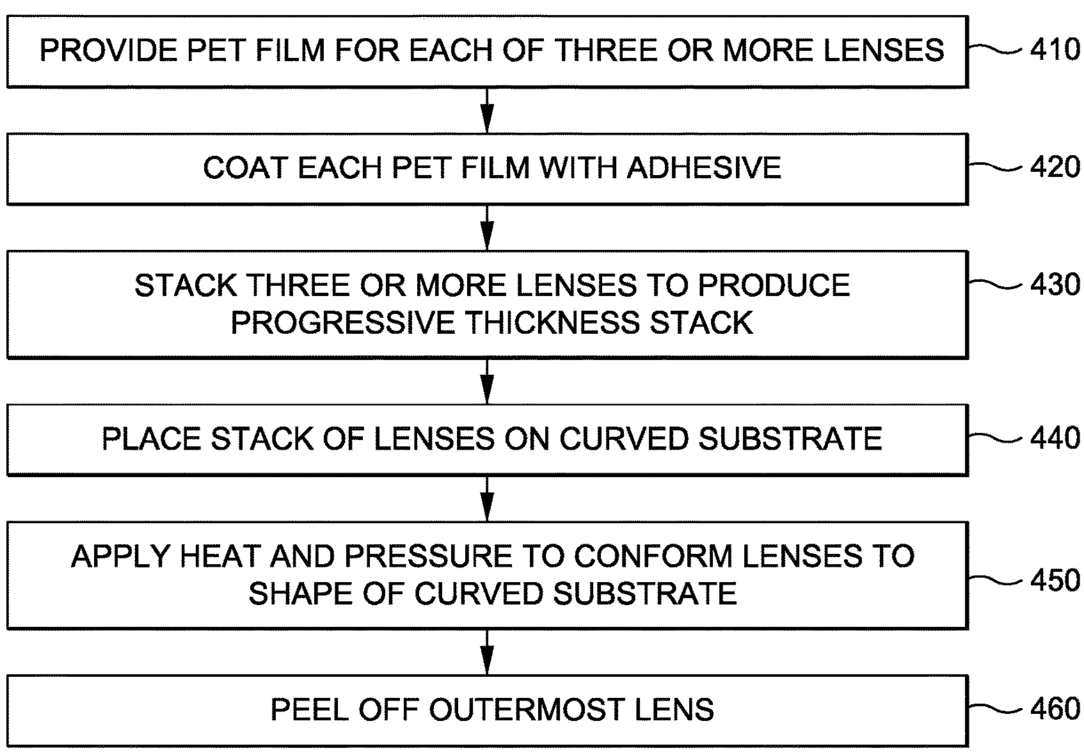

PROVIDE PET FILM FOR EACH OF THREE OR MORE LENSES
410
COAT EACH PET FILM WITH ADHESIVE
420
STACK THREE OR MORE LENSES TO PRODUCE PROGRESSIVE THICKNESS STACK
430
PLACE STACK OF LENSES ON CURVED SUBSTRATE
440
APPLY HEAT AND PRESSURE TO CONFORM LENSES TO SHAPE OF CURVED SUBSTRATE
450
PEEL OFF OUTERMOST LENS
460

FIG. 4

MULTI-LAYER WINDSHIELD FILM HAVING PROGRESSIVE THICKNESS LAYERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application relates to and claims the benefit of U.S. Provisional Application No. 63/267,686, filed Feb. 8, 2022 and entitled "MULTI-LAYER WINDSHIELD FILM HAVING PROGRESSIVE THICKNESS LAYERS," the entire contents of which is expressly incorporated by reference.

STATEMENT RE: FEDERALLY SPONSORED RESEARCH/DEVELOPMENT

Not Applicable

BACKGROUND

For participants in motorsports such as stock car racing and off-road racing, it is important to maintain visibility of the course as mud, bugs, and other debris accumulate on the windshield of the vehicle and as the windshield becomes pitted by hard debris such as rocks. The same is true, though on a more gradual scale, for ordinary street vehicles. In addition, auto racers and ordinary street vehicle owners alike have a need to protect the underlying windshield from pitting or cracking in view of the high expense and inconvenience of replacing it. Indeed, this aspect of the problem is even more pronounced in the case of street vehicles due to the much greater number of street vehicles in existence and the higher cost of glass windshields in comparison to polycarbonate windshields as are typically used in racecars. To meet these needs, tearoff films are commonly employed, either individually or in laminated stacks, which may be applied to any type of vehicle windshield. As debris accumulates on the outermost tearoff film, or as the outermost film becomes pitted and otherwise damaged, the driver simply tears it off to reveal the next pristine film underneath. Depending on the number of films in the stack, the process may be repeated several times before replacing the stack.

It has been found by the present inventors that much of the protective benefit of a laminated stack of tearoff films comes from its total thickness as it serves to cushion the impact of hard debris. Unfortunately, this potential benefit is at odds with its functionality as a laminated stack since each removed film dramatically reduces the thickness of the stack, resulting in a reduced resistance to impact and a significantly increased likelihood that the underlying windshield will become damaged by debris while the stack is in use. Moreover, there is a performance tradeoff between the impact cushioning effect and the increased distortion associated with the use of relatively thicker films.

BRIEF SUMMARY

The present disclosure contemplates various systems and methods for overcoming the above drawbacks accompanying the related art. One aspect of the embodiments of the present disclosure is a protective barrier affixable to a curved substrate. The protective barrier may comprise a stack of three or more lenses. Each of the three or more lenses may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film or a thermoplastic polyurethane (TPU) film) and an adhesive layer on a first side of the thermoplastic film. The three or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses.

The thermoplastic films of the three or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses. The thermoplastic film of an innermost lens of the stack may be at least twice as thick as the thermoplastic film of an outermost lens of the stack, preferably at least three times as thick.

The thermoplastic film of an innermost lens of the stack may have a thickness of five mil or greater. The thickness of the thermoplastic film of the innermost lens of the stack may be seven mil or less, preferably six mil or less.

The thermoplastic film of an outermost lens of the stack may have a thickness of three mil or less. The thickness of the thermoplastic film of the outermost lens of the stack may be two mil or greater.

The adhesive layers of the three or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses. The adhesive layer of an innermost lens of the stack may be at least twice as thick as the adhesive layer of an outermost lens of the stack. The adhesive layer of the innermost lens of the stack may be at least three times as thick as the adhesive layer of the outermost lens of the stack.

The thermoplastic films of the three or more lenses may have respective thicknesses that include at least two different thicknesses.

The adhesive layers of the three or more lenses may have respective thicknesses that include at least two different thicknesses.

The three or more lenses may number at least four. At least two of the lenses may have the same thickness.

A total thickness of the stack may be between ten mil and thirty mil. The total thickness of the stack may be between fifteen mil and twenty-five mil.

Another aspect of the embodiments of the present disclosure is a system. The system may comprise a vehicle windshield and a protective barrier affixed to the vehicle windshield. The protective barrier may comprise a stack of three or more lenses. Each of the three or more lenses may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film or a thermoplastic polyurethane (TPU) film) and an adhesive layer on a first side of the thermoplastic film. The three or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses.

The vehicle windshield may be a windshield of a street vehicle.

Another aspect of the embodiments of the present disclosure is a method. The method may comprise stacking three or more lenses. Each of the three or more lenses may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film or a thermoplastic polyurethane (TPU) film) and an adhesive layer on a first side of the thermoplastic film. The three or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses. The method may further comprise placing the stack of three or more lenses on a curved substrate with the adhesive layer of an innermost lens of the stack in contact with the curved substrate and applying heat and pressure to conform the stack of three or more lenses to the shape of the curved substrate.

The method may comprise peeling off an outermost lens of the stack of three or more lenses after said applying heat and pressure.

Another aspect of the embodiments of the present disclosure is a protective barrier affixable to a curved substrate. The protective barrier may comprise a stack of two or more lenses. Each of the two or more lenses may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film or a thermoplastic polyurethane (TPU) film) and an adhesive layer on a first side of the thermoplastic film. The adhesive layers of the two or more lenses may have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least two different thicknesses.

Another aspect of the embodiments of the present disclosure is a protective barrier affixable to a curved substrate, the protective barrier comprising a stack of one or more lenses, each of the one or more lenses including a thermoplastic polyurethane (TPU) film and an adhesive layer on a first side of the TPU film.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the various embodiments disclosed herein will be better understood with respect to the following description and drawings, in which like numbers refer to like parts throughout, and in which:

FIG. **1** is a cross-sectional view of a protective barrier according to an embodiment of the present disclosure;

FIG. **2** is an exploded view of the protective barrier;

FIG. **3** is a cross-sectional view of another protective barrier according to an embodiment of the present disclosure; and

FIG. **4** is an example operational flow according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

The present disclosure encompasses various embodiments of a protective barrier affixable to a curved substrate such as a vehicle windshield and methods of manufacture, installation, and use thereof. The detailed description set forth below in connection with the appended drawings is intended as a description of several currently contemplated embodiments and is not intended to represent the only form in which the disclosed invention may be developed or utilized. The description sets forth the functions and features in connection with the illustrated embodiments. It is to be understood, however, that the same or equivalent functions may be accomplished by different embodiments that are also intended to be encompassed within the scope of the present disclosure. It is further understood that relational terms such as first and second and the like are used solely to distinguish one from another entity without necessarily requiring or implying any actual such relationship in order between such entities.

FIG. **1** is a cross-sectional view of a protective barrier **100** according to an embodiment of the present disclosure. The protective barrier **100** may be affixed to a substrate **10** such as a windshield of an automobile and may comprise a stack of three or more lenses **110** (or in some cases two or more lenses **110**) such as the lenses **110***a*, **110***b*, **110***c* shown in FIG. **1**. Each of the lenses **110** may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film) **112** and an adhesive layer **114** on a first side thereof for bonding the lenses **110** together and to the substrate **10**. Unlike conventional stacks of tearoff films, the three or more lenses **110** may have respective thicknesses that define a monotonically decreasing function (i.e., one that either decreases or stays the same but does not increase) in a stacking direction of the stack (i.e., from a lens **110** nearest the substrate **10** toward a lens **110** farthest from the substrate **10**). The respective thicknesses of the three or more lenses **110** may further include at least three different thicknesses arranged accordingly, with each change in thickness thus being a decrease, resulting in thinner lenses **110** being arranged later in the stacking direction (though the stack may include adjacent lenses **110** whose respective thicknesses are the same). As shown by way of example in FIG. **1**, the three illustrated lenses **110***a*, **110***b*, **110***c* may have respective thicknesses D_a, D_b, D_c that are all different and which decrease from a first (innermost) lens **110***a* closest to the substrate **10** to a last (outermost) lens **110***c* farthest from the substrate **10**, i.e., $D_a>D_b>D_c$. Owing to the described construction, as compared to conventional stacks where all layers have the same thickness, the protective barrier **100** may maintain a greater total remaining thickness as each lens **110** is removed. As a result, the peeling away of each lens **110** during the life of the protective barrier **100** does not degrade the cushioning effect of the stack as much, affording better protection of the substrate **10** against harmful impacts. At the same time, the novel construction of the protective barrier **100** makes it possible to achieve a desired performance balance by combining the cushioning effect of relatively thicker films with the reduced distortion of relatively thinner films.

FIG. **2** is an exploded view of the protective barrier **100** shown in FIG. **1**. In general, the different thicknesses D_a, D_b, D_c may be achieved by adjusting the thickness of any sub-layer of each lens **110**. Thus, in the illustrated example, where each lens **110** has a thermoplastic film **112** and an adhesive layer **114**, the different thicknesses D_a, D_b, D_c may be the result of varying the thickness(es) of one or both of these two layers **112**, **114** in each lens **110**. For the sake of example, FIGS. **1** and **2** show one such possibility in which both the thickness of the thermoplastic film **112** and the thickness of the adhesive layer **114** decrease in the stacking direction. In particular, in the illustrated example, the respective thickness of the thermoplastic films **112**, identified as d_{1a}, d_{1b}, and d_{1c} in FIG. **2**, have the relationship $d_{1a}>d_{1b}>d_{1c}$, and the respective thicknesses of the adhesive layers, identified as d_{2a}, d_{2b}, and d_{2c} in FIG. **2**, likewise have the relationship $d_{2a}>d_{2b}>d_{2c}$. However, either of these relationships may, on its own, produce the relationship $D_a>D_b>D_c$, with the thicknesses of the other layer (i.e., the thicknesses of the thermoplastic films **112** or the thicknesses of the adhesive layers **114**) remaining constant or having a different relationship, for example.

More generally, and accounting for embodiments in which there may be adjacent lenses **110** having the same thickness, the thermoplastic films **112** of the three or more lenses **110** may have respective thicknesses that define a monotonically decreasing function in the stacking direction. Additionally, or alternatively, the adhesive layers **114** of the three or more lenses **110** may have respective thicknesses that define a monotonically decreasing function in the stacking direction. In addition, either the respective thicknesses of the thermoplastic films **112** or the respective thicknesses of the adhesive layers **114**, or both, may include at least two different thicknesses or, in some cases, three or more thicknesses. For example, one practical implementation may be to produce thermoplastic films **112** of three or more different thicknesses and to stack them so that the thermoplastic films **112** have monotonically decreasing thickness in the stacking direction, possibly keeping the thicknesses of the adhesive layers **114** constant. In such a stack, the thermoplastic film **112** of an innermost lens **110** of the stack may be at least twice as thick as the thermoplastic film **112** of an outermost lens **110** of the stack, for example, preferably at least three times as thick. Another practical implementation may be to produce thermoplastic films **112** having the same thickness but to apply differing amounts of adhesive thereto so that the adhesive layers **114** have monotonically decreasing thickness in the stacking direction. In such a stack, the adhesive layer **114** of an innermost lens **110** of the stack may be at least twice as thick as the adhesive layer **114** of an outermost lens **110** of the stack, for example, preferably at least three times as thick. Between these two extremes, the thicknesses of the thermoplastic films **112** or the thicknesses of the adhesive layers **114** may transition gradually from the thickest thermoplastic film **112** or thickest adhesive layer **114** of the innermost lens **110** to the thinnest thermoplastic film **112** or thinnest adhesive layer **114** of the outermost lens **110**. Preferably, and as described in more detail below, the thicknesses of the thermoplastic films **112** or adhesive layers **114** may transition not perfectly evenly but in discrete stages in order to maximize the remaining total thickness of the stack as much as possible as each lens **110** is removed.

FIG. **3** is a cross-sectional view of another protective barrier **300** according to an embodiment of the present disclosure. Like the protective barrier **100**, the protective barrier **300** may be affixed to a substrate **10** such as a windshield of an automobile and may comprise a stack of three or more lenses **110** (or in some cases two or more lenses **110**), in this case the lenses **110***a*, **110***b*, and **110***c* and an additional lens **110***c*. Each of the lenses **110** may be the same as those described in relation to FIG. **1** and may include a thermoplastic film (preferably a polyethylene terephthalate (PET) film) **112** and an adhesive layer **114** on a first side thereof for bonding the lenses **110** together and to the substrate **10**. The example of the protective barrier **300** of FIG. **3** is provided in order to illustrate that the monotonically decreasing function described above may allow for adjacent lenses **110** whose respective thicknesses are the same. In this regard, FIG. **3** illustrates the specific case where the thinnest lens **110***c* (having thickness D_c) is repeated. More generally, any of the lenses **110** may be repeated any number of times within the meaning of the monotonically decreasing function contemplated herein. For example, there may be two lenses **110***a*, two lenses **110***b*, and two lenses **110***c*, or there may be three lenses **110***a*, one lens **110***b*, and three lenses **110***c*. Thus, for example, the three or more lenses **110** contemplated may number four or more, with two (or more) of the lenses having the same thickness. It should also be noted that there is no limitation on the number of differently fabricated lenses **110** having different thicknesses. That is, there may also be one or more lenses **110***d* with thickness D_a (where $D_a<D_c$), one or more lenses **110***e* with thickness D_e (where $D_e<D_a$), etc. Typically, however, the total number of lenses **110** may be five or less so as not to introduce too much optical distortion to the protective barrier **100**.

In general, the thicknesses of the lenses **110** of the protective barriers **100**, **300** contemplated herein may transition evenly from the thickest (innermost) lens **110** to the thinnest (outermost) lens **110** or may, preferably, transition in discrete stages in order to maximize the remaining total thickness of the stack as much as possible as each lens **110** is removed. As a numeric example, the following Table 1 compares the remaining stack thickness in mil as each lens **110** is removed in three hypothetical protective barriers. In each case, the starting total thickness of the stack is 20.00 mil and there are four lenses **110**. Though the specific constraints on each lens's thickness may depend on the quality or strength of PET used (e.g., higher quality PET may allow for thinner thermoplastic films **112**) and on the particular application (e.g., thicker thermoplastic films **112** may be usable when a higher degree of optical distortion is acceptable), it is assumed in each case that the thinnest usable thermoplastic film **112** is 2.00 mil and the thickest usable thermoplastic film **112** is 7.00 mil. (However, it is noted that stronger PET may make 1.00 mil thermoplastic films **112** possible in some cases.) For purposes of this example, it is also assumed that the thickness of the adhesive layer **114** is kept constant at 0.50 for each lens **110**, with the total thickness of each lens **110** thus ranging from 2.50 mil to 7.50 mil.

TABLE 1

Lens #	Constant Thickness	Progressive Thickness 1	Progressive Thickness 2
4 (outermost)	5.00 (20.00 left)	2.50 (20.00 left)	2.50 (20.00 left)
3	5.00 (15.00 left)	4.17 (17.50 left)	3.00 (17.50 left)
2	5.00 (10.00 left)	5.83 (13.33 left)	7.00 (14.50 left)
1 (innermost)	5.00 (5.00 left)	7.50 (7.50 left)	7.50 (7.50 left)

In Table 1, the protective barrier labeled "Constant Thickness" has four equally thick lenses **110** of 5.0 mil each, while the two protective barriers labeled "Progressive Thickness 1" and "Progressive Thickness 2" exhibit monotonically decreasing thickness from the innermost lens to the outermost lens including at least three thicknesses as described herein. As can be seen from a comparison between the different hypothetical protective barriers in Table 1, the total remaining thickness in the "Progressive Thickness 1" and "Progressive Thickness 2" examples is significantly greater than that in the "Constant Thickness" example as each lens **110** is removed, such that the remaining stack provides a superior cushioning effect to withstand impacts. For example, after the outermost lens (lens number 4) is removed, the "Constant Thickness" stack has gone from a total thickness of 20.00 mil down to a total thickness of 15.00 mil, while the two "Progressive Thickness" examples have only dropped to a total thickness of 17.50 mil. The "Progressive Thickness" examples continue to preserve more total thickness as the lenses **110** are removed. The monotonic decrease in thickness of "Progressive Thickness 1" represents an even transition in which the change in thickness is constant from one lens **110** to the next, while the monotonic decrease in thickness of "Progressive Thickness 2" represents an uneven transition marked by discrete stages, such that there is a stage of relatively thin lenses **110** on the outermost part of the stack (2.50 mil and 3.00 mil) and a stage of relatively thick lenses **110** on the innermost part of the stack (7.00 mil and 7.50 mil). By arranging the thicknesses of the lenses **110** in this way, the remaining thickness as each lens **110** is removed can be further optimized. As can be seen, for example, "Progressive Thickness 2" retains 14.50 mil total thickness after the second lens **110** is removed, while "Progressive Thickness 1" retains only 13.33 mil total thickness (though this is still far superior to the 10.00 mil total thickness retained by the "Constant Thickness" example). In this way, an uneven transition between the thickest and thinnest lenses **110** may result in a greater total thickness remaining after each lens **110** is removed, further optimizing the protective barrier **100** for protection against impacts during use.

In the above examples described in relation to Table 1, the thicknesses of the adhesive layers **114** are assumed to be kept constant at 0.50 mil, with the thicknesses of the thermoplastic films **112** being 4.50 mil in the "Constant Thickness" example and transitioning from 7.00 mil to 2.00 mil in the two examples of progressive thickness ("Progressive Thickness 1" and "Progressive Thickness 2"). In general, when implementing the disclosed monotonic decrease in thickness, it is contemplated that the thermoplastic film **112** of the innermost lens **110** of the stack, as well as the thermoplastic films **112** of those lenses **110** nearest it, may preferably be relatively thick (e.g., five mil or greater) so that the greatest portion of the total thickness of the protective layer **100** is concentrated at the innermost part of the stack. At the same time, the thickness of this innermost thermoplastic film **112** preferably does not exceed seven mil (and more preferably does not exceed six mil) in order to keep the degree of optical distortion within a range that is suitable for a windshield use case. As for the thermoplastic film **112** of the outermost lens **110** of the stack and those lenses **110** nearest it, the thickness is preferably three mil or less so that the first lenses **110** that are removed from the stack do not significantly reduce the total thickness of the stack. At the same time, the thickness of the outermost thermoplastic film **112** (i.e., the minimum film thickness) is typically at least two mil or greater so that it is strong enough to withstand the forces associated with the user peeling lenses **110** from the stack during use. It is noted, however, that since the outermost thermoplastic film **112** does not need to undergo the pulling force of any previous (i.e., higher) adhesive layer, the thermoplastic film **112** of the outermost lens **110** may in some cases be significantly thinner than the thermoplastic film **112** of the lens **110** underneath it.

As noted above, the different thicknesses D_a, D_b, D_c may be achieved by adjusting the thickness of any sub-layer of each lens **110**, including the adhesive layers **114**. In this regard, the thickness of the adhesive layer **114** may typically be varied between a minimum thickness that is 0.050 mil or greater and a maximum thickness that is 2.00 mil or less, for example.

FIG. **4** is an example operational flow according to an embodiment of the present disclosure. The operational flow of FIG. **4** may serve as an example method of manufacturing, installing, and using the protective barrier **100**, **300** including the stack of lenses **110** shown and described in relation to FIGS. **1-3**. The operational flow may begin with providing the thermoplastic film **112** to be used in each of three or more lenses **110** (step **410**). The thermoplastic film **112** of each of the lenses **110** may be a biaxially-oriented polyethelene terephthalate (BoPET) and may be selected for particular MTF data or may be fabricated while actively monitoring the MTF data in a continuous or batch-to-batch process as described in any of U.S. Patent Application Pub. No. 2021/0162645, entitled "Method and Apparatus for Reducing Non-Normal Incidence Distortion in Glazing Films," U.S. Patent Application Pub. No. 2021/0283994, entitled "Protective Barrier for Safety Glazing," or commonly owned U.S. patent application Ser. No. 17/505,433, entitled "Method and Apparatus for Reducing Non-Normal Incidence Distortion in Glazing Films," the entire contents of each of which is incorporated by reference herein. In this regard, providing the thermoplastic film **112** may include, for example, melting a resin, extruding the melted resin through a die to produce a polymer film, and cooling the polymer film. Each thermoplastic film **112** may be coated on one side thereof with an adhesive layer **114** (step **420**), which is preferably wet deposited but may be applied according to any appropriate methods including spin coating, dip coating, or vacuum deposition. The adhesive layer **114** may be a wet mount adhesive as disclosed, for example, in U.S. Pat. No. 9,128,545, entitled "Touch Screen Shield" or a dry mount adhesive as disclosed, for example, in U.S. Pat. No. 9,295,297, entitled "Adhesive Mountable Stack of Removable Layers," the entire contents of each of which is incorporated by reference herein. The adhesive **114** may be an acrylic or silicon adhesive such as an acrylic pressure sensitive adhesive (PSA) or a silicon PSA.

With the thermoplastic films **112** having been coated with the adhesive layers **114**, the operational flow of FIG. **4** may continue with stacking three or more of the resulting lenses **110** to produce a progressive thickness stack (step **430**). For example, as described above, either the thickness of the thermoplastic films **112**, the thickness of the adhesive layers **114**, or both may be varied according to a monotonically decreasing function from an innermost lens **110** to an outermost lens **110**, such that the thickness of each lens **110** is either less than or equal to that of the previous lens **110** in the stacking direction. In addition to the thermoplastic film **112** and adhesive layer **114**, it is contemplated that each lens **110** may further include other layers, such as a hard coat as described in the above-mentioned '994 publication, a UV blocking layer, or a thermochromic film as described in U.S. Patent Application Pub. No. 2021/0070017, entitled "Nano Particle Solar Control Film," the entire contents of which is incorporated by reference herein. The thicknesses of any such additional layers may likewise be controlled in order to maintain the monotonically decreasing thickness described herein. The total thickness of the stack of lenses **110** may preferably be between ten mil and thirty mil, more preferably between fifteen mil and twenty-five mil (e.g., twenty mil as in the above examples of Table 1). In order to keep optical distortion as low as possible, the refractive indices of the thermoplastic films **112**, the adhesive layers **114**, and any other layers within each lens **110** and between each of the plurality of lenses **110** may be matched to within 0.2 as described in the above-mentioned '297 patent.

Once the protective barrier **100** comprising the stack of lenses **110** has been assembled, the operational flow may continue with installing the protective barrier **100** on a curved substrate **10** such as the windshield of a car or other vehicle. Continuing to refer to the operational flow of FIG. **4**, the protective barrier **100**, including the stack of lenses **110**, may be placed on the windshield or other curved substrate **10** (step **440**), with the adhesive layer **114** of the lowermost lens **110***a* (see FIGS. **1-3**) in contact with the curved substrate **10**. For easier installation, the protective barrier **100** may be rough cut (e.g. using an electric film cutter) so as not to extend too far outside the windshield **10**. The operational flow may continue with applying heat and pressure to conform the stack of three or more lenses **110** to the shape of the curved substrate **10** (step **450**). In particular, the applying of heat and pressure may be performed at least in part prior to the adhesive layer **114** of each of the three or more lenses **110** being fully cured, for example, prior to the adhesive layer **114** exceeding a peel strength of 25 grams per inch determined as a constant load per unit width needed for peeling. The protective barrier **100** may be completely conformed to the shape of the curved substrate **10** prior to the adhesive layers **114** being fully cured. In some cases, the protective barrier **100** may be applied to the substrate **10** using a sacrificial layer serving as a female mold cavity to sandwich the stack of lenses **110** between the sacrificial layer and the substrate **10** as described in U.S. Patent

Application Pub. No. 2020/0247102, entitled "Thermoform Windshield Stack with Integrated Formable Mold," the entire contents of which is incorporated by reference herein. After allowing the protective barrier **100** to cool down, the installation may conclude with performing a final trim to fit the windshield or other substrate **10**.

As explained above, it is contemplated that a protective barrier **100** having more than one lens **110** may allow for the outermost lens **110** to be peeled off and removed to reveal the unused surface of the lens **110** beneath. In this respect, the operational flow of FIG. **4** may continue during the life of the protective barrier **100** that has been installed on a vehicle windshield or other substrate **10**. When the outermost lens **110** becomes unacceptably degraded over time (e.g. after six months, after a year, after scratching from wiper blades begins to occur, etc.), it may be peeled off to reveal the next lens **110** underneath (step **460**). The timing of peeling off the outermost lens **110** may depend on the particular climate where the protective barrier **100** is used, with some climates entailing more exposure to sun and others requiring more frequent use of wiper blades, for example. Owing to the progressive thickness of the stack of lenses **110**, the total thickness of the protective barrier **100** may remain significantly greater than a conventional stack of tearoff lenses after the removal of the outermost lens **110**, resulting in a longer lasting cushioning effect against impacts during the life of the protective barrier **100**.

In the above disclosure, it is noted that PET (e.g., BoPET) may be a preferred thermoplastic film **112**. However, the material of the thermoplastic film **112** is not necessarily limited in this respect. For example, the thermoplastic film **112** of any or all of the lenses **110** may instead be a thermoplastic polyurethane (TPU) film, such as an optically clear TPU film. The TPU film may be manufactured to have a visible light transmittance (VLT) of greater than 85% (e.g., 90-95%) while having a low haze (e.g., 1% or lower). The TPU film may be greater than 2 mils, for example. Advantageously, the use of TPU for the thermoplastic film **112** of the protective barrier **100** may allow for a quicker installation process, requiring less expertise on the part of the installer, as compared to when PET is used. This is due to TPU's ease of applicability on 2D or 3D curved surfaces, without there being the need to apply heat to thermoform the film or the stack, or with only the need to apply very little heat to thermoform the TPU in seconds when the film is to be installed. In particular, TPU is more stretchable than PET and also requires less heat to become increasingly more stretchable. Common issues, such as fingering (i.e., imperfect application resulting in finger-shaped bubbles underneath the film), that occur when installing a PET-based stack require a specific thermoforming technique to avoid and/or correct. Correcting these imperfections itself is a lengthy process, resulting in longer installation time by a professional. In contrast, TPU with strong elasticity and elongation properties doesn't require as much technique and in some cases may not require any professional technique.

As a result of the above advantages, the use of TPU for the thermoplastic film(s) **112** may allow for a significantly lower installation cost than that of PET-based thermoplastic film(s) **112**, resulting in a highly affordable product. Such an affordable product is especially important as a protective barrier for the underlying windshield as windshields become increasing costly due to Advanced Driver Assistance Systems (ADAS) technology, the increased windshield curvature of new car designs, and the larger windshield size of new car designs. It is also contemplated that TPU-based films **112**, with or without a protective hard coat, may last longer than PET-based films **112**. As such, the use of TPU in the disclosed embodiments (as well as for protective films in general, even single-layer stacks as described below) may result in a lower cost film, a significantly shorter installation time (e.g., one-fifth the installation time), a longer lifetime, and a lower cost per windshield per year (e.g., one-tenth of the cost in the case of PET-based protective films) as the underlying windshields are protected from breaking, cracking, or pitting.

Furthermore, when a windshield is replaced in the U.S., even if it can be recycled by being sent to a third-party recycling company, over 95% of the time the old windshield is not recycled. The vast majority of the estimated 15 million windshields damaged are being dumped in landfills each year in the U.S. alone, resulting in massive pollution. See Wölfel B, Seefried A, Allen V, Kaschta J, Holmes C, Schubert D W. *Recycling and Reprocessing of Thermoplastic Polyurethane Materials towards Nonwoven Processing*. Polymers. 2020; 12(9):1917. https://doi.org/10.3390/polym12091917. By using a stack of one or more protective TPU films, a significant portion of this waste can be avoided. Meanwhile, the TPU itself can be easily recycled and is a 100% recyclable and biodegradable material. It is an advanced material much more environmentally friendly than alternatives such as PVC since TPU is recyclable and biodegradable in three to five years, in comparison to glass windshield material that may take hundreds of thousands of years to decompose in the landfill assuming it decomposes at all.

Advantageously, it is contemplated that TPU-based films **112** may replace PET-based films **112** in the disclosed protective barrier **100** as described above. However, the above disclosure regarding the advantages of using TPU-based films **112** is not intended to be limited only to use in the protective barrier **100** described herein. TPU-based films **112** may, for example, be used in other multi-layer stacks of lenses **110** or in single-layer stacks of one lens **110**. A contemplated single-layer stack of one lens **110** may include, for example, the TPU film **112** and the adhesive layer **114** for bonding the lens **110** to the substrate **10**, as well as optionally a hard coat, a UV blocking layer, a thermochromic film, etc. as described above.

The above description is given by way of example, and not limitation. Given the above disclosure, one skilled in the art could devise variations that are within the scope and spirit of the invention disclosed herein. Further, the various features of the embodiments disclosed herein can be used alone, or in varying combinations with each other and are not intended to be limited to the specific combination described herein. Thus, the scope of the claims is not to be limited by the illustrated embodiments.

What is claimed is:

1. A protective barrier affixable to a curved substrate, the protective barrier comprising a stack of four or more lenses, each of the four or more lenses including a thermoplastic film and an adhesive layer on a first side of the thermoplastic film, the four or more lenses having respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses, wherein a difference in thickness between adjacent lenses of the stack is not constant.

2. The protective barrier of claim **1**, wherein the thermoplastic films of the four or more lenses have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses.

3. The protective barrier of claim 2, wherein the thermoplastic film of the innermost lens of the stack is at least twice as thick as the thermoplastic film of the outermost lens of the stack.

4. The protective barrier of claim 1, wherein the thermoplastic film of the innermost lens of the stack has a thickness of five mil or greater.

5. The protective barrier of claim 4, wherein the thickness of the thermoplastic film of the innermost lens of the stack is seven mil or less.

6. The protective barrier of claim 1, wherein the thermoplastic film of the outermost lens of the stack has a thickness of three mil or less.

7. The protective barrier of claim 6, wherein the thickness of the thermoplastic film of the outermost lens of the stack is two mil or greater.

8. The protective barrier of claim 1, wherein the adhesive layers of the four or more lenses have respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses.

9. The protective barrier of claim 8, wherein the adhesive layer of the innermost lens of the stack is at least twice as thick as the adhesive layer of the outermost lens of the stack.

10. The protective barrier of claim 9, wherein the adhesive layer of the innermost lens of the stack is at least three times as thick as the adhesive layer of the outermost lens of the stack.

11. The protective barrier of claim 1, wherein the thermoplastic films of the four or more lenses have respective thicknesses that include at least two different thicknesses.

12. The protective barrier of claim 1, wherein the adhesive layers of the four or more lenses have respective thicknesses that include at least two different thicknesses.

13. The protective barrier of claim 1, wherein at least two of the lenses have the same thickness.

14. The protective barrier of claim 1, wherein a total thickness of the stack is between ten mil and thirty mil.

15. The protective barrier of claim 14, wherein the total thickness of the stack is between fifteen mil and twenty-five mil.

16. The protective barrier of claim 1, wherein the thermoplastic film of each of the four or more lenses is a polyethylene terephthalate (PET) film.

17. The protective barrier of claim 1, wherein the thermoplastic film of each of the four or more lenses is a thermoplastic polyurethane (TPU) film.

18. A method comprising:

providing the protective barrier of claim 1;

placing the stack of four or more lenses on a curved substrate with the adhesive layer of the innermost lens of the stack in contact with the curved substrate; and

applying heat and pressure to conform the stack of four or more lenses to the shape of the curved substrate.

19. The method of claim 18, further comprising peeling off the outermost lens of the stack of four or more lenses after said applying heat and pressure.

20. The method of claim 18, wherein the thermoplastic film of each of the four or more lenses is a polyethylene terephthalate (PET) film.

21. The method of claim 18, wherein the thermoplastic film of each of the four or more lenses is a thermoplastic polyurethane (TPU) film.

22. A system comprising:

a vehicle windshield; and

a protective barrier affixed to the vehicle windshield, the protective barrier comprising a stack of four or more lenses, each of the four or more lenses including a thermoplastic film and an adhesive layer on a first side of the thermoplastic film, the four or more lenses having respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses, wherein a difference in thickness between adjacent lenses of the stack is not constant.

23. The system of claim 22, wherein the vehicle windshield is a windshield of a street vehicle.

24. The system of claim 22, wherein the thermoplastic film of each of the four or more lenses is a polyethylene terephthalate (PET) film.

25. The system of claim 22, wherein the thermoplastic film of each of the four or more lenses is a thermoplastic polyurethane (TPU) film.

26. A protective barrier affixable to a curved substrate, the protective barrier comprising a stack of four or more lenses, each of the four or more lenses including a thermoplastic film and an adhesive layer on a first side of the thermoplastic film, the thermoplastic films of the four or more lenses having respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses, wherein a difference in thickness between the thermoplastic films of adjacent lenses of the stack is not constant.

27. The protective barrier of claim 26, wherein the thermoplastic films of at least two of the lenses have the same thickness.

28. A protective barrier affixable to a curved substrate, the protective barrier comprising a stack of four or more lenses, each of the four or more lenses including a thermoplastic film and an adhesive layer on a first side of the thermoplastic film, the adhesive layers of the four or more lenses having respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses, wherein a difference in thickness between the adhesive layers of adjacent lenses of the stack is not constant.

29. The protective barrier of claim 28, wherein the adhesive layers of at least two of the lenses have the same thickness.

30. A system comprising:

a vehicle windshield; and

a protective barrier affixed to the vehicle windshield, the protective barrier comprising a stack of four or more lenses, each of the four or more lenses including a thermoplastic film and an adhesive layer on a first side of the thermoplastic film, the thermoplastic films of the four or more lenses having respective thicknesses that define a monotonically decreasing function in a stacking direction of the stack and that include at least three different thicknesses, wherein a difference in thickness between the thermoplastic films of adjacent lenses of the stack is not constant.

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